Performance Evaluation of Iranian Electricity Distribution Units by Using Stochastic Data Envelopment Analysis

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Abstract

This paper introduces an approach based on stochastic data envelopment analysis (SDEA) for performance assessment of electricity distribution units. A new approach is applied for assessment of Iranian distribution units from 2001 to 2011 in this paper. There are usually incomplete and stochastic data or lack of data with respect to electricity distribution companies. Due to lack of information about some parameters, theory of probability is imported to the model. Different Iranian distribution units are considered as decision making units (DMUs). Network length, transport capacity and the number of employees are chosen as inputs while number of customers and total electricity sales are chosen as stochastic outputs. Then, the best electricity distributions units are selected with respect to efficiency scores in stochastic environment. Also, SDEA model is performed for each input, separately to identify the most important input indicators by comparing the results of associated efficiencies with SDEA model. The empirical results show that network length is identified as the most important and influential

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input factor in this particular case study. To the best of our knowledge this is the first paper that examines stochastic outputs for assessment of electricity distribution units by SDEA in Iran.

Keywords: Electricity Distribution Units; Assessment; Performance Measures; Stochastic Data Envelopment Analysis; Network length

1. Introduction

Energy is one of the basic concerns after starting the industrial revolution. Therefore, improving the efficiency of electricity distributions is an important issue around the world. There are different parametric and non-parametric methods for estimating efficiency scores of electricity distribution units. Also, different indicators for measuring the efficiency of electricity distributions such as price or revenue cap regulation schemes, sliding-scale, rate of return, partial cost adjustment, menu of contracts, yardstick regulation, etc. are taken into account in previous studies such as Comnes et al. (1995), Hill (1995), Joskow and Schmalensee (1986), Jamasb and Pollitt (2001) and Hall (2000).

Electricity industry plays an important role in the development of the countries. Assessment of the electricity distribution industry plays an important role in improving the performance. Therefore, in this study, a new approach is applied for assessment of Iranian distribution units over the period 2001-2011 to improve the performance. In this regards, 17 Iranian electricity distribution units are considered as the decision making units in this study. The main objective of this study is assessment of electricity distribution units with respect to five important indicators, which considered by Omrani et al. (2010), including network length, transport capacity, number of employees, number of customers, and total electricity sales using SDEA approach. In addition, the most important input indicators are identified to enhance the performance of each electricity distribution unit.

The rest of this paper is organized as follows. The relevant literature has been reviewed in Section 2. The proposed approach is presented in Section 3. The implementation procedure of the approach for evaluation the performance of electricity distribution units is investigated in Section 4 and the paper is concluded in Section 5.

2. Literature Review

In the last decade, assessment of the power sector performance has been gained increasing attentions. Policy making, performance optimization and assessment of electricity distribution units are very important issues for regulators in the electricity restructuring and reform. Indeed, the efficiency levels of various methodologies are employed to set x-factors in the incentive regulation approaches such as revenue cap and price cap regulation. Debreu (1951) and Farrell (1957) introduced the concept of global technical efficiency and practical application of this theory had been established later in two category namely parametric and non-parametric approach. The parametric approaches apply statistical techniques whilst non-parametric approaches use linear and non-linear programming techniques such as data envelopment analysis (DEA) (Fallahi et al., 2011).

There are several studies about efficiency estimation electricity distribution units. Data envelopment analysis (DEA) is an ideal approach to evaluate the performance of various systems with multiple inputs and output. DEA is a popular optimization method for measuring the relative efficiency of decision making units (DMUs). Fallahi et al. (2011) used DEA approach to assess the performance of power electric generation management companies. They considered installed capacity, fuel, labor, electricity used, average operational, time, and net electricity

produced as key performance indicators (KPIs). In addition, the efficient company was identified in their study.

Azadeh et al. (2009) presented a deterministic approach for performance assessment of electricity distribution units in Iran. They used DEA and principle component analysis (PCA) in their proposed approach. Network length, transformers capacity, number of employees, unit's delivery, and service area had been considered as major indicators in their study. In another study, Azadeh et al. (2009a) presented an approach based on DEA, corrected ordinary least squares (COLS), stochastic frontier analysis (SFA), and PCA methods for efficiency estimation of electricity distribution units. They selected the optimum DEA model for their particular case study. In addition, electricity distribution units had been evaluated and optimized through their proposed approach. They considered number of employees, operating costs, network length, transformer capacity, number of customers, size of service area, and unit's delivery as the most widely used indicators for evaluation of electricity distribution units.

DEA and window analysis (WA) were applied by Sözen et al. (2012) for efficiency assessment of ten hydro-power plants. They used DEA with respect to the production and energy unit cost in order to optimize hydro-power plants. See et al. (2012) presented SFA method for calculating technical efficiency levels of Malaysian thermal power plants. Fuel, labor, production indicator, and unit's delivery are chosen as input and output variables in their study. They demonstrated that plant size and fuel type have a significant impact on the performance.

An interactive robust data envelopment analysis (IRDEA) model was applied by Sadjadi et al. (2011) to determine the input and output target values of electricity distribution companies. In their study, network length, transport capacity, number of employees, number of customers,

and total electricity sales are considered for assessment by IRDEA. Also, Omrani et al. (2010) considered these indicators to evaluate efficiency of Iranian electricity distribution units by using COLS and PCA. Lei and Feng (2012) and Amina, et al. (2012) presented forecasting problems in flied of with respect to price and consumption in power generation units.

In terms of the impact of the most important contextual variables on efficiency scores in electricity industries, Zhang and Bartels (1998) used DEA to study the effect of sample size on the mean productive efficiency of firms in electricity distribution in Australia, Sweden and New Zealand. By using Monte Carlo simulation, they showed that the mean efficiency is related to the sample size. Giannakis and Louis (2011) presented a quality-incorporated benchmarking study of the electricity distribution utilities in the UK between 1991/92 and 1998/99. They found that cost-efficient companies did not necessarily exhibit high service quality and that efficiency scores of cost-only models did not show high correlation with those of quality-based models. Their results showed that integrating quality of service in regulatory benchmarking is preferable to cost-only approaches.

Pacudan and De Guzman (2002) used DEA analyzed the productive efficiency and simulated the effect of the energy efficiency policy on the productive efficiency of the electricity distribution industry in the Philippines. They showed that the energy efficiency policy which benefits the overall economy and whole electricity supply industry results also in productive efficiency improvement in the distribution sector of the industry. Von Hirschhausen et al. (2006) applied non-parametric (DEA) and parametric tests to evaluate the efficiency of electricity distribution industries in Germany. In this study, the inputs include capital, labor, and peak load capacity, and units sold and the number of customers are output. The data cover 307 German

electricity distribution industries. The results indicate that returns to scale play but a minor role; only very small utilities have a significant cost advantage.

In estimating efficiency measures of the electric distribution industry in the previous studies, the different variables as inputs and outputs are adopted. The inputs which are frequently used in these studies include: actual number of employees (the number of employee); network losses (in GWh); and circuit km of network line (in kilometers) (Bagdadioglu et al., 1996; Pacudan and De Guzman, 2002). The number of employees represents labor input. Circuit km of network line and network loss denote capital inputs. Also the outputs variables include: actual number of customers (the number of customers); electricity sales (in GWh); and service area (in square kilometers). The number of customers shows the number of nodes the utility must supply. Many firms consist of geographically large distribution territories encompassing several cities, while others contain only a single city. The service area captures the effects of franchise area requirements and also consider the sparsely settled area. Both the km² of service area and the number of customers denote customer density. It should be noted that electricity sales contain all power deliveries to final consumer units.

In this paper, due to the lack of information about some parameters a stochastic DEA model is applied for evaluation shaping factor for performance assessment of electricity distribution units with respect to five important indicators including network length, transport capacity, number of employees, the number of customers, and total electricity sales. These indicators are frequently applied for assessment of electricity distribution units (Jamasb and Pollitt, 2000). As mentioned before, network length, transport capacity, and the number of employees are controllable and deterministic indicators and are considered as inputs whilst

number of customers and total electricity sales are uncontrollable and stochastic indicators and are chosen as outputs.

To the best of our knowledge, this is the first study that presents a novel approach for performance assessment of electricity distribution units with stochastic outputs. In addition, this study identifies important input indicators and weight of each input indicators have been achieved base on accurate mathematical modeling. The proposed approach is applied to Iranian distribution units from 2001 to 2011. The results of this approach can help managers and decision makers to improve the performance.

2.1. Motivation and Significance

There are usually incomplete and stochastic data or lack of data with respect to electricity distribution units. This means data could not be analyzed by the deterministic models. Therefore, due to lack of information about some parameters, theory of probability should be imported to previous models. In this regard, new approaches for tackling such stochastic problems are required. This gap motivated the authors to develop a unique approach to handle such gaps for evaluating stochastic environment. Moreover, SDEA is developed and applied for evaluation of electricity distribution units.

In addition, five important indicators including network length, transport capacity, number of employees, number of customers, and total electricity sales are considered in this study to evaluate different electricity distribution units. Network length, transport capacity, and the number of employees are controllable and deterministic indicators and are considered as inputs. In other hand, the number of customers and total electricity sales are uncontrollable and stochastic indicators and are chosen as outputs. It is therefore quite essential to identify

influential controllable indicators. Decision makers can improve performance by focusing on these important indicators. This paper identifies important controllable indicators for assessment of electricity distribution units. Also, weights of each controllable indicators are calculated through an accurate mathematical model whilst these weight are obtained based on expert opinions in previous studies. To the best of our knowledge, this is the first study that presents a novel approach for evaluation electricity distribution units with stochastic indicators and identification of the most important input indicators.

3. Methodology

In this paper a stochastic DEA approach is used to evaluate electricity distribution units. Then, the most important input indicators are identified. SDEA is utilized to rank different electricity distribution units with respect to a set of key performance indicators in order to determine the optimum performance and identify the most important input indicators. Figure 1 presents a schematic view of the proposed approach in this study. In summary, the proposed approach is achieved as follows:

Step1: Collect the required data for electricity distribution units. The required data is collected from 2001 up to 2011 from publications of Iran Power Generation, Transmission and Distribution Management Company.

Step2: Define inputs and outputs of SDEA model. Outputs of this model are considered stochastic. Network length, transformers capacity and number of employees are chosen as inputs whilst number of customers and total electricity sales are chosen as stochastic outputs.

Step 3: Define mean and standard deviation of each output indicator. The mean of each indicator during the 2001 to 2011 is considered as the value of each indicator. For output indicators, the standard deviation of each outputs is computed based on data from 2001 to 2011.

Step 4: Apply SDEA model for evaluating electricity distribution units.

Step 5: Select the best α for SDEA model through noise analysis.

Step 6: Validate and verify the results of DEA model through statistical experiment.

Step 7: Perform sensitivity analysis. To this end, apply SDEA model by omitting input indicators one by one, separately.

Step 8: Identify the most important input indicators by comparing the results of the sensitivity analysis.

Step 9: Compute weight of each factor based on results of sensitivity analysis.

Figure 1: Schematic view of the proposed approach for evaluation of electricity distribution units

3.1. Data Collection

One of the important steps in the proposed algorithm is data collection. The results are not reliable, if this data are not collected correctly. In this paper, data is obtained from Iran Power Generation, Transmission and Distribution Management Company publications. As stated

before, network length, transformers capacity and number of employee are considered as inputs variables and number of customers and total electricity sales are considered as outputs variables. These variables are frequently used in previous studies such as Omrani et al. (2010). [Output indicators are considered as stochastic data set](#). In addition, for performing SDEA model, mean and standard deviation of the outputs variables are calculated.

3.2. Stochastic DEA

Data envelopment analysis (DEA) is an ideal approach to evaluate the performance of various systems with multiple inputs and output. DEA is a widely used optimization method for measuring the relative efficiency of decision making units (DMUs). [This method is valuable decision support tool for calculating efficiency and evaluation of different systems \(Omrani et al., 2010; Sengupta, 1987\)](#). In addition, efficient and inefficient units have been recognized by applying this approach (Charnes et al., 1978) and decision makers can improve the weaknesses of their organizations. This approach can apply multiple input and output indicators to compute efficiency scores, simultaneously (Serrano Cinca et al., 2006). DEA approach is a familiar deterministic approach for performance assessment but there are usually incomplete and stochastic data or lack of data with respect to electricity distribution units. This means data could not be collected and analyzed by deterministic models. To deal with this problem, stochastic model has been used in this study.

Sengupta (1987) introduced DEA model in stochastic case study. SDEA model deals with stochastic inputs and outputs. Stochastic data variations in indicators can be imported into the DEA model and provide a more accurate model for assessment of stochastic environments (Sengupta, 1987). Therefore, SDEA is a proper decisional approach to assessment different

decision making units in stochastic environment whilst basic DEA model only works with certain indicators. In addition, basic DEA model is not accurate when faces with risk (Sueyoshi, 2000; Wu and Lee, 2010). The main advantage of SDEA is an accurate prediction in future decisions (Mirbolouki et al., 2013).

Sueyoshi (2000) introduced a CCR stochastic model that can be used for future planning. His proposed model can handle stochastic outputs and creates accurate results when there is incomplete information. Indeed, manager can control inputs of their organization whilst they are unable to control outputs because outputs are affected by external factors (Sueyoshi, 2000). Model (1) shows stochastic CCR which introduced by Sueyoshi (2000).

$$\begin{aligned}
 & \text{Max} \sum_{r=1}^s u_r \bar{y}_{rk} \\
 & \text{s.t.} \\
 & \sum_{i=1}^m v_i x_{ik} = 1 \\
 & \sum_{i=1}^m v_i (\beta_j x_{ij}) - \sum_{r=1}^s u_r \{ \bar{y}_{rj} + b_{r,j} F^{-1}(1 - \alpha_j) \} \geq 0 \quad j = 1, \dots, n \\
 & u_r, v_i \geq 0
 \end{aligned} \tag{1}$$

The stochastic CCR Model (1) evaluates the relative efficiencies of n DMUs ($j=1 \dots 17$), each with m inputs and s outputs denoted by x_{ij} and y_{rj} , respectively. In model (1), u_r and v_i are the factor weights. $b_{r,j}$ is standard deviation of y_{rk} and $\bar{y}_{rk}$ is the mean of y_{rk} . Sueyoshi (2000) considered α_j as a risk criterion representing of decision makers and β_j as an expected efficiency level of the j th DMU (See Sueyoshi, 2000). Expected efficiency level for j th DMU is equal to 1 in this particular case study. In addition, α_j demonstrates risk of environment.

In this study, there are three inputs and two outputs. The network length, transformers capacity and the number of employees are considered as inputs. The number of customers and total electricity sales are considered as outputs. In addition, 17 different electricity units are considered as DMUs. The mean of each indicator during the 2001 to 2011 is considered as the value of each indicator. For output indicators, the standard deviation of each outputs is computed based on data from 2001 to 2011.

3.3. Noise Analysis

For choosing the best α in SDEA model, noise analysis is performed for each α level. To do this, value of one indicator for one DMU is multiplied by 10, randomly. Then, SDEA model applied for different α . This procedure is performed for 10 experiments. Finally, p-value of normality test is calculated for each experiment at different levels of α . Model with the higher average p-value will be selected for evaluation performance assessment (Azadeh et al., 2013). In this study, this analysis is applied for selecting the best α parameters of SDEA model.

3.4. Sensitivity Analysis

As mentioned before, identifying the most influential input indicators for performance assessment is an important issue. This can help policy makers to have a more comprehensive and thorough understanding about indicators that have more effect on the system's performance. To do this, a sensitivity analysis has been performed. In this regard, SDEA model has been run three times for each input indicators, separately. In each run, the data set of one input must be eliminated. Then, correlation coefficient between results of SDEA after and before removing of each input are calculated. Low value for correlation shows the importance of omitted input.

In Table 1, features of this approach are compared with the previous studies to show its advantages and superiorities.

Table 1: The proposed approach for assessment of electricity distribution units vs. other methods

Method	Features								
	Multiple inputs and outputs	Data complexity and non-linearity	Stochastic Data	Sensitivity Analysis	Data Pre-processing and post-processing	Optimization	Identification of important factors	Calculated weight factor by mathematical modeling	Practicability in real world cases
The proposed method	✓	✓	✓	✓	✓	✓	✓	✓	✓
Omrani et al. (2010)	✓	✓			✓	✓			✓
Azadeh et al. (2009)	✓	✓		✓	✓	✓			✓
Sözen et al. (2012)	✓	✓			✓	✓			✓
Sadjadi et al. (2011)	✓	✓	✓		✓	✓			✓

4. Case Study

In this section, Iranian electricity distribution units are considered as the experiment of this study. The proposed approach is applied to Iranian distribution units from 2001 to 2011. In this study, 17 units of Iranian distribution units are considered as DMUs. The network length, transformers capacity and the number of employees are chosen as inputs while the number of customers and total electricity sales are chosen as stochastic outputs. As mentioned before, these variables are frequently used by previous studies such as (Omrani et al., 2010). The measurement units for the network length, transformers capacity and total electricity sales are kilometer (km), MVA and MWh, respectively. Our data sets involve annual data on 17 units observed over the eleven-year period from 2001 to 2011. This data is obtained from Iran Power Generation,

Transmission and Distribution Management Company publications. The number of customers and total electricity sales are not deterministic. Table 2 shows the raw data of Iranian electricity distribution units for 2001. Data for other years are shown in [Tables 10 to 19 of Appendix I](#).

Table 2: Data for electricity distribution units (2001)

2001	Network length	Transport capacity	Number of employees	Number of customer	Total electricity sales
Esfahan	37747.30	4100.60	4045.00	1408544.00	10899900.00
Azerbaijan	50958.00	3524.00	4259.00	1737246.00	6055061.00
Bakhtar	38389.74	3262.90	3319.00	1035574.00	7533912.00
Tehran	47861.00	11166.00	8655.00	4040018.00	21339882.00
Khorasan	51622.00	3714.00	4471.00	1638911.00	8018057.00
Zanjan	18311.34	558.71	1150.00	476785.00	2968774.00
Semnan	7354.12	680.30	608.00	170057.00	1433864.00
Systan - Baluchestan	14309.67	951.66	1706.00	293300.00	1448853.00
Gharb	27366.78	2148.70	1984.00	768800.00	2768793.00
Kerman	25026.00	1449.00	2291.00	525678.00	4253445.00
Kish	689.55	165.49	161.00	10309.00	201653.00
Gilan	20288.60	1413.82	2149.00	678213.00	2339062.00
Mazandaran	31341.19	2750.10	2444.00	1137302.00	4216201.00
Hormozgan	14678.00	1591.00	2163.00	254376.00	3613971.00
Yazd	9479.82	831.54	952.00	295591.00	2166935.00
Khuzestan 3	245080.00	5955.95	6481.00	788655.00	11286739.00
Fars1	39452.00	4142.00	3611.00	1086094.00	6625987.00

4.1. Inputs and Outputs of SDEA Model

In this study, SDEA is applied for ranking DMUs with respect to five important indicators. These indicators are applied for assessment of electricity distribution units, frequently (Jamasp and Pollitt, 2000; Omrani et al., 2010). Network length, transport capacity and the number of employees are chosen as inputs while the number of customers and total electricity sales are chosen as stochastic outputs. Mean and standard derivation is calculated for stochastic indicators of each DMUs. Due to lack of information about some outputs variables, they are

considered as stochastic data sets. The mean of each indicator during the 2001 to 2011 is considered as the value of each indicator. The standard deviation of each output is computed based on data from 2001 to 2011. The results are shown in Tables 3 and 4.

Table 3: Mean of indicators for each DMU

Mean	Network length	Transport capacity	Number of employees	Number of customers	Total electricity sales
Esfahan	46639.12	5552.37	2178.27	673474.10	15761464.45
Azerbaijan	58576.64	4532.87	3194.45	653070.27	7310036.09
Bakhtar	43194.89	4334.48	1925.09	485824.99	10154339.73
Tehran	60704.45	14747.38	7383.82	2025151.64	28827170.82
Khorasan	63148.09	4888.59	2693.91	784804.04	12032029.82
Zanjan	20870.94	2000.54	722.09	228229.30	4653825.73
Semnan	8923.74	870.63	379.73	84128.50	1993341.55
Systan - Baluchestan	21901.15	1449.53	1023.36	152518.19	2496980.27
Gharb	32681.80	2642.64	1175.91	366351.99	4135314.18
Kerman	36803.91	2915.09	1213.55	266953.91	6263096.72
Kish	13072.28	1368.75	218.00	227644.00	943638.00
Gilan	22705.96	1890.64	1100.73	409489.50	3503522.18
Mazandaran	30523.20	4215.13	1522.82	438400.39	6012477.45
Hormozgan	17843.09	2291.00	1107.00	113915.70	6025715.36
Yazd	13533.07	7117.84	19727.73	130705.96	3348636.09
Khuzestan 3	53833.00	8117.88	2982.45	398050.68	16878761.09
Fars1	50858.91	6214.21	2023.64	527308.72	11033563.01

Table 4: Standard deviation of indicators for each DMU

Standard Deviation	Network length	Transport capacity	Number of employees	Number of customers	Total electricity sales
Esfahan	-	-	-	923307.32	3221180.48
Azerbaijan	-	-	-	988360.68	2498110.22
Bakhtar	-	-	-	662872.25	1870250.01
Tehran	-	-	-	2736129.94	4234524.74
Khorasan	-	-	-	1067783.54	2535521.37
Zanjan	-	-	-	311546.77	1216274.74
Semnan	-	-	-	114420.21	395995.60
Systan - Baluchestan	-	-	-	224299.04	790050.46
Gharb	-	-	-	500367.46	913768.67

Table 4: Standard deviation of indicators for each DMU

Standard Deviation	Network length	Transport capacity	Number of employees	Number of customers	Total electricity sales
Kerman	-	-	-	348064.72	1446953.42
Kish	-	-	-	481231.09	1393309.97
Gilan	-	-	-	635069.24	1605073.93
Mazandaran	-	-	-	630442.39	1689707.03
Hormozgan	-	-	-	153876.97	1595633.68
Yazd	-	-	-	174506.48	940319.45
Khuzestan 3	-	-	-	547736.16	4264519.80
Fars1	-	-	-	735396.90	2966711.63

4.2. Results of SDEA Model

SDEA models at different levels of α are performed for assessment of electricity units in this study. The efficiency scores for each unit at different levels of α are shown in Table 5.

Table 5: Efficiency results for SDEA

Efficiency	α							
	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7
Esfahan	0.749	0.749	0.853	0.903	0.951	1	1.391	3.551
Azerbaijan	0.425	0.462	0.498	0.555	0.631	0.756	1.235	3.126
Bakhtar	0.618	0.618	0.704	0.763	0.785	0.854	1.129	2.918
Tehran	0.689	0.689	0.816	0.88	0.94	1	2.643	3.424
Khorasan	0.651	0.796	0.74	0.783	0.867	1	1.323	3.484
Zanjan	0.647	0.647	0.753	0.805	0.847	0.91	1.281	3.512
Semnan	0.604	0.604	0.688	0.729	0.787	0.807	1.019	2.545
Systan - Baluchistan	0.454	0.454	0.518	0.548	0.595	0.683	0.881	2.283
Gharb	0.413	0.413	0.482	0.537	0.627	0.789	1.222	3.517
Kerman	0.567	0.567	0.646	0.684	0.72	0.757	0.989	2.472
Kish	0.347	0.347	0.446	0.559	0.707	1	2.15	11.604
Gilan	0.497	0.497	0.611	0.694	0.809	1	2.3	4.764
Mazandaran	0.418	0.418	0.478	0.529	0.607	0.746	1.181	3.334
Hormozgan	0.697	0.697	0.818	0.868	0.915	1	1.051	1.242
Yazd	0.35	0.35	0.408	0.439	0.471	0.504	0.538	0.991
Khuzestan 3	0.707	0.707	0.825	0.883	0.94	1	1.124	1.633

Table 5: Efficiency results for SDEA

Efficiency	α							
	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7
Fars1	0.537	0.537	0.634	0.681	0.716	0.766	1.046	2.944

For selection the best α_j for this particular case study, $\alpha_j = 0.1, 0.2, 0.3, 0.4, 0.5, 0.6$, and 0.7 are considered. The results of SDEA for $\alpha=0.5$ are shown in Tables 6. To select the best α_j , noise analysis, which introduced in previous sections, is performed for each α_j . The results of other noise analysis are shown in Tables 20 to 26 of Appendix II.

Table 6: Efficiency results for SDEA with noisy data ($\alpha=0.05$)

$\alpha=0.05$	1	2	3	4	5	6	7	8	9	10
Esfahan	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749
Azarbayejan	0.444	0.251	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.462
Bakhtar	0.646	0.618	0.538	0.618	0.618	0.618	0.618	0.618	0.618	0.618
Tehran	0.689	0.689	0.689	0.689	0.689	0.689	0.689	0.689	0.689	0.689
Khorasan	0.665	0.651	0.651	0.743	0.651	0.651	0.649	0.651	0.651	0.796
Zanjan	0.7	0.647	0.647	0.647	0.647	0.647	0.647	0.647	0.647	0.647
Semnan	0.636	0.604	0.604	0.604	0.528	0.604	0.604	0.604	0.604	0.604
Systan - Baluchistan	0.464	0.454	0.454	0.454	0.454	0.253	0.454	0.454	0.454	0.454
Gharb	0.443	0.413	0.413	0.413	0.413	0.413	0.334	0.413	0.413	0.413
Kerman	0.661	0.567	0.567	0.567	0.567	0.567	0.567	0.476	0.567	0.567
Kish	0.292	0.347	0.347	0.347	0.347	0.347	0.347	0.347	0.347	0.347
Gilan	0.522	0.497	0.497	0.497	0.497	0.497	0.497	0.497	0.497	0.497
Mazandaran	0.472	0.418	0.418	0.418	0.418	0.418	0.418	0.418	0.418	0.418
Hormozgan	0.697	0.697	0.697	0.697	0.697	0.697	0.697	0.697	0.697	0.697
Yazd	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Khuzestan 3	0.707	0.707	0.707	0.707	0.707	0.707	0.707	0.707	0.707	0.707
Fars1	0.582	0.537	0.537	0.537	0.537	0.537	0.537	0.537	0.537	0.537

To select the optimum α , 10 experiments are performed for each α level. In each experiment one indicators for one DMU is multiplied by 10, randomly. Then, normality test is performed on efficacy score with noisy data by MINITAB® and the best α is selected based on maximum average p-value. Table 7 shows p-value of normality test for different α .

Table 7: P-value for normality test

α	1	2	3	4	5	6	7	8	9	10	Average
0.05	0.07	0.455	0.459	0.322	0.416	0.345	0.311	0.239	0.328	0.681	0.3626
0.1	0.081	0.262	0.497	0.699	0.339	0.455	0.465	0.348	0.341	0.344	0.3831
0.2	0.124	0.22	0.29	0.238	0.174	0.279	0.277	0.349	0.295	0.277	0.2523
0.3	0.05	0.223	0.274	0.188	0.129	0.236	0.255	0.416	0.312	0.277	0.236
0.4	0.117	0.471	0.515	0.739	0.35	0.57	0.518	0.375	0.533	0.259	0.4447
0.5	<0.005	<0.005	<0.005	0.008	<0.005	0.009	0.006	0.017	0.012	<0.005	0.0077
0.6	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
0.7	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

According to Table 7, for $\alpha=0.4$, average of p-value is higher than other α . So, this α must be selected for SDEA model. As seen in Table 5, Esfahan has the best performance at $\alpha=0.4$. This unit can be selected as benchmarked unit for future decisions and planning.

4.3. Validation and Verification

The proposed model must be validated and verified by other models. In this study, SDEA model under deterministic condition is compared with deterministic DEA to demonstrate its acceptable performance. To this end, stochastic and deterministic DEA are compared for validation and verification. In SDEA model, if $b_{rj} = 0$ and the value of output equals to mean the result of SDEA and deterministic DEA must be similar. Table 8 shows deterministic CCR and stochastic CCR under this condition.

Table 8: Compare deterministic and stochastic (when $b_{rj}=0$)

Efficiency	Deterministic output-oriented CCR	Stochastic output-oriented CCR
Esfahan	1	1
Azarbayejan	0.756	0.756
Bakhtar	0.854	0.854

Table 8: Compare deterministic and stochastic (when $b_{rj}=0$)

Efficiency	Deterministic	Stochastic
Tehran	1	1
Khorasan	1	1
Zanjan	0.91	0.91
Semnan	0.807	0.807
Systan - Baluchistan	0.683	0.683
Gharb	0.789	0.789
Kerman	0.757	0.757
Kish	1	1
Gilan	1	1
Mazandaran	0.746	0.746
Hormozgan	1	1
Yazd	0.504	0.504
Khuzestan 3	1	1
Fars1	0.766	0.766

According to Table 8 these two models have same results. Correlation analysis was performed for the result of these models by MINITAB[®]. Moreover, Pearson correlation is equal to one. Thus, the SDEA is validated and verified by deterministic DEA under above condition.

4.4. Importance of Input Indicators

As mentioned before, manager can control inputs of their organization whilst they are unable to control outputs because outputs are affected by external factors. In addition, managers can improve performance of their organizations by controlling of inputs. Therefore, identification of important indicators can help decision makers to enhance their performance. To select the most important input indicators, SDEA model is performed three times for each input. Table 9 shows the results of the sensitivity analysis. Also, correlation coefficients between results of SDEA after and before the sensitivity analysis for each removed inputs are shown in Table 9.

Table 9: Efficiency results for SDEA model at $\alpha=0.4$

DMU	Removed input		
	Network length	Transport capacity	Number of employees
Esfahan	0.646	0.951	0.951
Azarbayejan	0.253	0.631	0.314
Bakhtar	0.453	0.785	0.693
Tehran	0.94	0.704	0.523
Khorasan	0.375	0.867	0.595
Zanjan	0.43	0.779	0.847
Semnan	0.427	0.767	0.69
Systan - Baluchistan	0.223	0.595	0.323
Gharb	0.256	0.611	0.483
Kerman	0.325	0.72	0.678
Kish	0.389	0.638	0.707
Gilan	0.403	0.809	0.452
Mazandaran	0.391	0.52	0.531
Hormozgan	0.635	0.881	0.715
Yazd	0.471	0.158	0.022
Khuzestan 3	0.94	0.696	0.744
Fars1	0.418	0.595	0.716
Correlation with SDEA	0.693	0.831	0.741

According to Table 9, elimination of network length has the greatest effect on the SDEA's results. Therefore, this input indicator is identified as the most important indicator in this particular case study through the proposed approach. Managers and decision makers can enhance performance of each electricity units by focusing on this important input indicators.

4.5. Weights of Input Indicators

Weight of each input indicators is calculated based on results of sensitivity analysis. In this regard, the percentage difference between correlation values for each removed input and 1 shows the weight of each input. Figure 2 shows these weights for this particular case study.

Figure 2: Weight of each input indicators in this particular case study

Referring to Figure 2, network length and the number of employees compose about 77% of total weights. Weight of network length is 42%, which shows the importance of this inputs for this case study.

5. Conclusion

In this paper, a stochastic data envelopment analysis (SDEA) was applied for assessment of electricity distribution units. This approach was used for evaluating different electricity distribution unit in Iran. The importance degree of each input indicator was identified through the proposed approach. There are usually incomplete and stochastic data or lack of data with respect to electricity distribution companies. Therefore, due to lack of information about some parameters, SDEA was applied for this study. Five important indicators including network length, transport capacity, the number of employees, the number of customers, and total electricity sales were considered to evaluate the performance of electricity distribution units.

Network length, transport capacity, and the number of employees were controllable and deterministic indicators and were considered as inputs and the number of customers and total electricity sales were uncontrollable and stochastic indicators and were considered as outputs. To identify the best SDEA model, the noise analysis was performed to select the best level of α for SDEA model. The results of selected SDEA showed that Esfehan has the best performance among electricity distribution units. This unit can be selected as benchmarked unit for future decisions and planning.

Identifying influential input indicators for performance assessment is an important issue. This is very helpful for managers to have a more comprehensive and thorough understanding about indicators that have more effect on system's performance. To do this, a sensitivity analysis was performed to identify these important indicators. The sensitivity results demonstrated that network length and the number of employees were the most important input indicators for this particular case study. In addition, the weight of network length indicator was 0.42, which showed importance of this input indicator in forming performance efficiency. Managers and decision makers can enhance performance of each electricity units by focusing on this important input indicators. To the best of our knowledge, this is the first study that presents a novel approach for performance assessment of electricity distribution units with stochastic outputs and identify the most important factor through accurate mathematical modelling.

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Appendix I: Raw Data

Table 10: Data for electricity distribution units (2002)

2002	Network length	Transport capacity	No. of employees	No. of customer	Total electricity sales
Esfahan	39634.00	4315.00	3984.00	1459338.00	11652381.00
Azerbaijan	53845.00	3678.00	4270.00	1809458.00	6385003.00
Bakhtar	37838.00	3416.00	3247.00	1072062.00	8048383.00
Tehran	54014.00	12412.00	8540.00	4334127.00	23083551.00
Khorasan	52345.00	3886.00	4561.00	1683766.00	8868613.00
Zanjan	18713.00	1661.00	1186.00	497281.00	3198700.00
Semnan	7607.00	699.00	612.00	179057.00	1534797.00
Systan - Baluchestan	15685.00	1006.00	1951.00	308580.00	1565183.00
Gharb	28305.00	755.00	1960.00	803127.00	2996889.00
Kerman	27752.00	1808.00	2164.00	556997.00	4285029.00
Kish	-	-	156.00	11828.00	221022.00
Gilan	20710.00	1461.00	2086.00	712964.00	2459212.00
Mazandaran	32589.00	2950.00	2409.00	1198865.00	4446624.00
Hormozgan	15834.00	1691.00	2169.00	269164.00	4242107.00
Yazd	9970.00	870.00	1002.00	326279.00	2497046.00
Khuzestan 3	28408.00	6410.00	6253.00	818771.00	12135834.00
Fars1	43409.00	4305.00	3491.00	1129456.00	7455615.00

Table 11: Data for electricity distribution units (2003)

2003	Network length	Transport capacity	No. of employees	No. of customer	Total electricity sales
Esfahan	41473.00	4555.00	1974.00	1519.94	12738011.00
Azerbaijan	55509.00	3844.00	2911.00	1880.81	6793703.00
Bakhtar	38923.00	3596.00	1789.00	1114.04	8514841.00
Tehran	52726.00	11897.00	30433.00	4571.71	25609592.00
Khorasan	57281.00	4098.00	2313.00	1779.16	9404952.00
Zanjan	19114.00	1734.00	653.00	519.32	3442033.00
Semnan	8064.00	730.00	374.00	186.78	1594953.00
Systan - Baluchestan	17779.00	1048.00	798.00	330.67	1695564.00
Gharb	29356.00	2383.00	1230.00	831.19	3258737.00
Kerman	30225.00	2040.00	1084.00	577.18	4823673.00
Kish	-	-	-	-	-
Gilan	21186.00	1534.00	938.00	742.00	2600089.00

Mazandaran	34124.00	3181.00	1474.00	1261.15	4778711.00
Hormozgan	16185.00	1786.00	938.00	288.54	4742554.00
Yazd	11990.00	963.00	576.00	340.53	2669038.00
Khuzestan 3	29646.00	6684.00	2414.00	859.32	13303894.00
Fars1	44928.00	4624.00	1995.00	1192.42	8396673.00

Table 12: Data for electricity distribution units (2004)

2004	Network length	Transport capacity	No. of employees	No. of customer	Total electricity sales
Esfahan	42972.00	4805.00	1893.00	1586.30	13798449.00
Azerbaijan	56951.00	4011.00	2795.00	1927.87	7228854.00
Bakhtar	40877.00	3855.00	1724.00	1172.43	9007012.00
Tehran	54987.00	12537.00	4041.00	4810.44	27292588.00
Khorasan	58845.00	4301.00	2191.00	1838.12	10535190.00
Zanjan	19598.00	1812.00	636.00	541.78	3957009.00
Semnan	8363.00	768.00	360.00	196.94	1777262.00
Systan - Baluchestan	19922.00	1131.00	797.00	352.24	1928811.00
Gharb	30437.00	2432.00	1146.00	859.65	3545622.00
Kerman	31554.00	2145.00	997.00	598.65	5855387.00
Kish	-	-	-	-	-
Gilan	21665.00	1634.00	900.00	777.33	2668952.00
Mazandaran	35619.00	3527.00	1449.00	1332.07	5295520.00
Hormozgan	16510.00	1865.00	924.00	304.90	5502997.00
Yazd	12595.00	1022.00	596.00	355.34	2909305.00
Khuzestan 3	30730.00	6949.00	2235.00	886.85	13928906.00
Fars1	46737.00	5141.00	1830.00	1251.02	8969383.00

Table 13: Data for electricity distribution units (2005)

2005	Network length	Transport capacity	No. of employees	No. of customer	Total electricity sales
Esfahan	44467.00	5103.00	1756.00	1662.06	15030781.00
Azerbaijan	55334.00	4110.00	2699.00	2003.57	7896263.00
Bakhtar	42060.00	4087.00	1615.00	1216.55	9311046.00
Tehran	58223.00	13243.00	3806.00	5019.69	28147247.00
Khorasan	60754.00	4517.00	2173.00	1919.97	11672591.00
Zanjan	20185.00	1913.00	622.00	561.13	3983770.00
Semnan	8646.00	784.00	342.00	205.13	1846006.00
Systan - Baluchestan	22968.00	1365.00	876.00	374.75	2151337.00
Gharb	31772.00	2550.00	1053.00	905.22	3864628.00

Kerman	37328.00	2609.00	948.00	622.92	5915235.00
Kish					
Gilan	22181.00	1746.00	750.00	811.19	2895883.00
Mazandaran	36992.00	3852.00	1360.00	1402.54	5771225.00
Hormozgan	17082.00	1950.00	904.00	337.91	6031783.00
Yazd	13022.00	1064.00	509.00	372.86	3274078.00
Khuzestan 3	32740.00	7479.00	2111.00	929.51	14722922.00
Fars1	48413.00	5436.00	1746.00	1307.60	10025277.00

Table 14: Data for electricity distribution units (2006)

2006	Network length	Transport capacity	No. of employees	No. of customer	Total electricity sales
Esfahan	46309.00	5413.00	1624.00	1745.80	15884273.00
Azerbaijan	57210.00	4362.00	3158.00	2083.70	8766284.00
Bakhtar	43155.00	4279.00	1544.00	1264.90	9785106.00
Tehran	60415.00	13687.00	3587.00	5254.20	29710279.00
Khorasan	65009.00	4866.00	2143.00	1999.20	12687079.00
Zanjan	20770.00	2035.00	602.00	586.10	4627296.00
Semnan	9049.00	843.00	317.00	213.70	1979703.00
Systan - Baluchestan	24598.00	1524.00	835.00	467.40	2505986.00
Gharb	32568.00	2659.00	897.00	952.80	4300071.00
Kerman	39082.00	3083.00	923.00	646.30	6830984.00
Kish					
Gilan	22597.00	1840.00	718.00	841.00	3075617.00
Mazandaran	38300.00	4139.00	1278.00	1482.50	6409714.00
Hormozgan	17629.00	2063.00	866.00	340.40	6600621.00
Yazd	13455.00	66011.00	477.00	387.80	3603417.00
Khuzestan 3	33853.00	7838.00	2105.00	975.80	16382160.00
Fars1	51205.00	6228.00	1644.00	1369.90	11084566.00

Table 15: Data for electricity distribution units (2007)

2007	Network length	Transport capacity	No. of employees	No. of customer	Total electricity sales
Esfahan	48218	5689	1633	1835	16794850.00
Azerbaijan	59719	4703	3112	2177	3101426.00
Bakhtar	44147	4496	1528	1320	10487158.00
Tehran	62218	15664	3794	5512	30966261.00
Khorasan	66086	5096	2194	2096	12823747.00
Zanjan	21411	2175	585	615	5729670.00
Semnan	9245	905	307	225	2027008.00

Systan - Baluchestan	26542	1606	821	425	2632679.00
Gharb	33550	2820	830	980	4607076.00
Kerman	40048	3293	922	673	6732974.00
Kish	-	-	-	-	-
Gilan	23076	1953	665	879	3284026.00
Mazandaran	39452	4428	1222	1559	6739852.00
Hormozgan	18018	2232	853	362	6648703.00
Yazd	13922	1232	476	409	4014579.00
Khuzestan 3	35011	8275	2097	1019	17376412.00
Fars1	52211.00	6440.00	1487.00	1439.00	12042883.00

Table 16: Data for electricity distribution units (2008)

2008	Network length	Transport capacity	No. of employees	No. of customer	Total electricity sales
Esfahan	49846.00	6079.52	1494.00	1929.00	18158021.00
Azerbaijan	61246.00	4979.62	2769.00	2309.00	9860557.00
Bakhtar	45956.00	4811.38	1459.00	1389.00	11481777.00
Tehran	66042.00	16725.19	3747.00	5666.00	30360639.00
Khorasan	67739.00	5363.47	2067.00	2210.00	13718117.00
Zanjan	22126.00	2325.20	537.00	649.00	5180132.00
Semnan	9466.00	957.62	285.00	235.00	2302397.00
Systan - Baluchestan	27420.00	1677.17	783.00	461.00	3432213.00
Gharb	34706.00	3046.31	773.00	1029.00	4452746.00
Kerman	41430.00	3594.00	867.00	721.00	6492820.00
Kish	-	-	-	-	443611.00
Gilan	23492.00	2056.25	612.00	923.00	3481712.00
Mazandaran	40897.00	4838.35	1171.00	1644.00	7194672.00
Hormozgan	18445.00	2411.00	824.00	381.00	7123016.00
Yazd	14401.00	1236.72	401.00	433.00	4326187.00
Khuzestan 3	36279.00	8730.71	1962.00	1092.00	19871699.00
Fars1	55335.00	6781.34	1346.00	1514.00	13177550.00

Table 17: Data for electricity distribution units (2009)

2009	Network length	Transport capacity	No. of employees	No. of customer	Total electricity sales
Esfahan	51948.00	6514.00	1395.00	2039420.00	18481377.00
Azerbaijan	63074.00	5265.00	2762.00	837465.00	10163640.00
Bakhtar	46736.00	5243.00	1397.00	1464300.00	12054168.00

Tehran	68607.00	17462.00	3753.00	6193313.00	32145292.00
Khorasan	69772.00	5638.00	2010.00	2350013.00	14175449.00
Zanjan	22636.00	2460.00	518.00	683545.00	5605774.00
Semnan	9916.00	1016.00	283.00	248854.00	2364016.00
Systan - Baluchestan	9916.00	1757.00	696.00	495437.00	3284082.00
Gharb	36393.00	3235.00	757.00	1087511.00	5069514.00
Kerman	43006.00	3821.00	838.00	770623.00	6794921.00
Kish	-	-	0.00	23301.00	496890.00
Gilan	24229.00	2194.00	650.00	970261.00	3616181.00
Mazandaran	-42352.00	5185.00	1251.00	1743528.00	7294597.00
Hormozgan	19138.00	2653.00	764.00	417858.00	7834218.00
Yazd	15997.00	1686.00	382.00	455316.00	4447248.00
Khuzestan 3	37980.00	9352.00	1913.00	1206176.00	20080773.00
Fars1	57247.00	7985.00	1296.00	1612796.00	13618811.00

Table 18: Data for electricity distribution units (2010)

2010	Network length	Transport capacity	No. of employees	No. of customer	Total electricity sales
Esfahan	54434.00	7009.00	2959.00	210992.00	19768506.93
Azerbaijan	64582.00	5547.00	3977.00	55284.00	3560516.00
Bakhtar	47986.00	5214.00	2456.00	151800.00	12755365.00
Tehran	70350.00	18253.00	7277.00	920688.00	34515674.02
Khorasan	71681.00	6004.00	3754.00	293742.00	15334828.00
Zanjan	23132.00	2604.00	961.00	77612.00	6252663.00
Semnan	10110.00	1061.00	451.00	35290.00	2522704.00
Systan - Baluchestan	30644.00	1899.00	1247.00	1541.00	3352982.00
Gharb	37175.00	3441.00	1567.00	121264.00	5355054.00
Kerman	44092.00	4017.00	1498.00	198761.00	8190113.90
Kish	-	-	170.00	4373.00	525000.00
Gilan	24886.00	2393.00	1428.00	151800.00	4042980.00
Mazandaran	43815.00	5584.00	2069.00	210992.00	4245620.00
Hormozgan	20856.00	3315.00	1378.00	55284.00	8915764.00
Yazd	16752.00	1763.00	864.00	62690.00	4760229.00
Khuzestan 3	40018.00	10394.00	3723.00	154990.00	23502415.00
Fars1	58941.00	8258.00	2539.00	121264.00	15041443.07

Table 19: Data for electricity distribution units (2011)

2011	Network length	Transport capacity	No. of employees	No. of customer	Total electricity sales
Esfahan	55982.00	7493.00	1204.00	2279643.00	20169559.00

Azerbaijan	65915.00	5838.00	2427.00	2731938.00	10599090.00
Bakhtar	49076.00	5419.00	1098.00	1612862.00	12718969.00
Tehran	72306.00	19175.00	3589.00	6757688.00	33927874.00
Khorasan	73495.00	6291.00	1756.00	2654570.00	15113705.00
Zanjan	23584.00	2728.00	493.00	771827.00	6246262.00
Semnan	10341.00	1133.00	238.00	290893.00	2544047.00
Systan - Baluchestan	31129.00	1980.00	747.00	576431.00	3469093.00
Gharb	37871.00	3599.00	738.00	1243612.00	5269326.00
Kerman	45300.00	4207.00	817.00	880595.00	8719482.00
Kish	25455.00	2572.00	603.00	1088409.00	3773652.00
Gilan	25455.00	2572.00	1212.00	1986173.00	8075030.00
Mazandaran	44978.00	5932.00	624.00	523036.00	9744516.00
Hormozgan	21899.00	3644.00	394.00	254376.00	5027135.00
Yazd	17280.00	1617.00	210770.00	295591.00	2166935.00
Khuzestan 3	42418.00	11229.00	1513.00	1404203.00	23074618.00
Fars1	61570.00	9016.00	1275.00	1842712.00	14931005.00

Appendix II: Sensitivity Analysis Results

Table 20: Efficiency results for SDEA with noisy data ($\alpha=0.1$)

$\alpha=0.1$	1	2	3	4	5	6	7	8	9	10
Esfahan	0.792	0.792	0.792	0.792	0.792	0.792	0.792	0.792	0.792	0.792
Azarbayejan	0.483	0.695	0.451	0.451	0.451	0.451	0.451	0.451	0.451	0.451
Bakhtar	0.691	0.654	0.572	0.654	0.654	0.654	0.654	0.654	0.654	0.654
Tehran	0.741	0.741	0.741	0.842	0.741	0.741	0.741	0.741	0.741	0.741
Khorasan	0.719	0.693	0.693	0.693	0.787	0.693	0.693	0.693	0.687	0.693
Zanjan	0.749	0.691	0.691	0.691	0.691	0.658	0.691	0.691	0.691	0.691
Semnan	0.681	0.639	0.639	0.639	0.639	0.639	0.564	0.639	0.639	0.639
Systan - Baluchistan	0.501	0.481	0.481	0.481	0.481	0.481	0.481	0.267	0.481	0.481
Gharb	0.481	0.437	0.437	0.437	0.437	0.437	0.437	0.437	0.363	0.437
Kerman	0.652	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.52
Kish	0.346	0.346	0.346	0.346	0.346	0.346	0.346	0.346	0.346	0.346
Gilan	0.571	0.538	0.538	0.538	0.538	0.538	0.538	0.538	0.538	0.538
Mazandaran	0.49	0.443	0.443	0.443	0.443	0.443	0.443	0.443	0.443	0.443
Hormozgan	0.747	0.747	0.747	0.747	0.747	0.747	0.747	0.747	0.747	0.747
Yazd	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374	0.374
Khuzestan 3	0.755	0.755	0.755	0.755	0.755	0.755	0.755	0.755	0.755	0.755
Fars1	0.638	0.576	0.576	0.576	0.576	0.576	0.576	0.576	0.576	0.576

Table 21: Efficiency results for SDEA with noisy data ($\alpha=0.2$)

$\alpha=0.2$	1	2	3	4	5	6	7	8	9	10
Esfahan	0.853	0.853	0.853	0.853	0.853	0.853	0.853	0.853	0.853	0.853
Azarbayejan	0.538	0.777	0.498	0.498	0.498	0.498	0.498	0.498	0.498	0.498
Bakhtar	0.759	0.704	0.62	0.704	0.704	0.704	0.704	0.704	0.704	0.704
Tehran	0.816	0.816	0.816	0.89	0.816	0.816	0.816	0.816	0.816	0.816
Khorasan	0.797	0.747	0.747	0.747	0.849	0.747	0.747	0.747	0.74	0.747
Zanjan	0.92	0.753	0.753	0.753	0.753	0.739	0.753	0.753	0.753	0.753
Semnan	0.746	0.688	0.688	0.688	0.688	0.688	0.614	0.688	0.688	0.688
Systan - Baluchistan	0.555	0.518	0.518	0.518	0.518	0.518	0.518	0.288	0.518	0.518
Gharb	0.537	0.482	0.482	0.482	0.482	0.482	0.482	0.482	0.405	0.482
Kerman	0.753	0.646	0.646	0.646	0.646	0.646	0.646	0.646	0.646	0.589
Kish	0.446	0.446	0.446	0.446	0.446	0.446	0.446	0.446	0.446	0.446
Gilan	0.642	0.611	0.611	0.611	0.611	0.611	0.611	0.611	0.611	0.611
Mazandaran	0.545	0.478	0.478	0.478	0.478	0.478	0.478	0.478	0.478	0.478
Hormozgan	0.818	0.818	0.818	0.818	0.818	0.818	0.818	0.818	0.818	0.818
Yazd	0.409	0.408	0.408	0.408	0.408	0.408	0.408	0.408	0.408	0.408
Khuzestan 3	0.825	0.825	0.825	0.825	0.825	0.825	0.825	0.825	0.825	0.825
Fars1	0.712	0.634	0.634	0.762	0.634	0.634	0.634	0.634	0.634	0.634

Table 22: Efficiency results for SDEA with noisy data ($\alpha=0.3$)

$\alpha=0.3$	1	2	3	4	5	6	7	8	9	10
Esfahan	0.903	0.903	0.903	0.903	0.903	0.903	0.903	0.903	0.903	0.903
Azarbayejan	0.582	0.848	0.555	0.555	0.555	0.555	0.555	0.555	0.555	0.555
Bakhtar	0.821	0.763	0.658	0.763	0.763	0.763	0.763	0.763	0.763	0.763
Tehran	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
Khorasan	0.862	0.784	0.784	0.783	0.901	0.784	0.784	0.784	0.783	0.784
Zanjan	0.962	0.805	0.805	0.805	0.805	0.805	0.805	0.805	0.805	0.805
Semnan	0.8	0.729	0.729	0.729	0.729	0.729	0.655	0.729	0.729	0.729
Systan - Baluchistan	0.6	0.548	0.548	0.548	0.548	0.548	0.548	0.305	0.548	0.548
Gharb	0.588	0.537	0.537	0.537	0.537	0.537	0.537	0.537	0.441	0.537
Kerman	0.791	0.684	0.684	0.684	0.684	0.684	0.684	0.684	0.684	0.644
Kish	0.564	0.559	0.559	0.559	0.559	0.559	0.559	0.559	0.559	0.559
Gilan	0.717	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694
Mazandaran	0.608	0.529	0.529	0.546	0.529	0.529	0.529	0.529	0.529	0.529
Hormozgan	0.878	0.868	0.868	0.868	0.868	0.868	0.868	0.868	0.868	0.868
Yazd	0.44	0.439	0.439	0.456	0.439	0.439	0.439	0.439	0.439	0.439
Khuzestan 3	0.883	0.883	0.883	0.883	0.883	0.883	0.883	0.883	0.883	0.883
Fars1	0.817	0.681	0.681	0.681	0.681	0.681	0.681	0.681	0.681	0.681

Table 23: Efficiency results for SDEA with noisy data ($\alpha=0.4$)

$\alpha=0.4$	1	2	3	4	5	6	7	8	9	10
Esfahan	0.951	0.951	0.951	0.951	0.951	0.951	0.951	0.951	0.951	0.951
Azarbayejan	0.637	0.406	0.631	0.631	0.631	0.631	0.631	0.631	0.631	0.631
Bakhtar	0.888	0.796	0.693	0.785	0.785	0.785	0.785	0.785	0.785	0.785
Tehran	0.94	0.94	0.94	0.964	0.94	0.94	0.94	0.94	0.94	0.94
Khorasan	0.927	0.867	0.867	0.867	0.949	0.867	0.867	0.867	0.867	0.867
Zanjan	0.991	0.847	0.847	0.847	0.847	0.847	0.847	0.847	0.847	0.847
Semnan	0.862	0.787	0.787	0.767	0.787	0.787	0.69	0.787	0.787	0.787
Systan - Baluchistan	0.646	0.595	0.595	0.595	0.595	0.595	0.595	0.335	0.595	0.595
Gharb	0.669	0.627	0.627	0.627	0.627	0.627	0.627	0.627	0.494	0.627
Kerman	0.82	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.945
Kish	0.715	0.707	0.707	0.707	0.707	0.707	0.707	0.707	0.707	0.707
Gilan	0.819	0.809	0.809	0.809	0.809	0.809	0.809	0.809	0.809	0.809
Mazandaran	0.687	0.607	0.607	0.665	0.607	0.607	0.607	0.607	0.607	0.607
Hormozgan	0.937	0.915	0.915	0.915	0.915	0.915	0.915	0.915	0.915	0.915
Yazd	0.471	0.471	0.471	0.541	0.471	0.471	0.471	0.471	0.471	0.471
Khuzestan 3	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
Fars1	0.815	0.717	0.717	0.717	0.717	0.716	0.717	0.717	0.717	0.717

Table 24: Efficiency results for SDEA with noisy data ($\alpha=0.5$)

$\alpha=0.5$	1	2	3	4	5	6	7	8	9	10
Esfahan	1	1	1	1	1	1	1	1	1	1
Azarbayejan	0.756	1	0.756	0.756	0.756	0.756	0.756	0.756	0.758	0.756
Bakhtar	0.98	0.854	0.752	0.854	0.854	0.854	0.854	0.854	0.856	0.854
Tehran	1	1	1	1	1	1	1	1	1	1
Khorasan	1	1	1	1	1	1	1	1	1	1
Zanjan	1	0.91	0.91	0.91	1	0.91	0.91	0.91	0.91	0.91
Semnan	0.936	0.807	0.807	0.807	0.807	0.725	0.807	0.807	0.807	0.807
Systan - Baluchistan	0.696	0.683	0.683	0.683	0.683	0.683	0.404	0.683	0.687	0.683
Gharb	0.818	0.789	0.789	0.789	0.789	0.789	0.789	0.634	0.789	0.789
Kerman	0.887	0.757	0.757	0.757	0.757	0.757	0.757	0.757	0.757	1
Kish	1	1	1	1	1	1	1	1	1	1
Gilan	1	1	1	1	1	1	1	1	1	1

Mazandaran	0.812	0.746	0.746	0.864	0.746	0.746	0.746	0.746	0.746	0.746
Hormozgan	1	1	1	1	1	1	1	1	1	1
Yazd	0.504	0.505	0.505	0.678	0.505	0.505	0.505	0.505	0.505	0.505
Khuzestan 3	1	1	1	1	1	1	1	1	1	1
Fars1	0.889	0.766	0.766	0.766	0.766	0.766	0.766	0.766	0.766	0.766

Table 25: Efficiency results for SDEA with noisy data ($\alpha=0.6$)

$\alpha=0.6$	1	2	3	4	5	6	7	8	9	10
Esfahan	1.358	1.391	1.391	1.437	1.391	1.391	1.391	1.391	1.391	1.391
Azarbayejan	1.235	1.057	1.235	1.235	1.235	1.235	1.235	1.235	1.235	1.235
Bakhtar	1.197	1.129	1.527	1.129	1.129	1.129	1.129	1.129	1.129	1.129
Tehran	2.643	2.643	2.643	2.643	2.643	2.643	2.643	2.643	2.643	2.643
Khorasan	1.339	1.323	1.323	1.323	1.525	1.323	1.323	1.323	1.323	1.323
Zanjan	1.34	1.281	1.281	1.281	1.281	1.183	1.281	1.281	1.281	1.281
Semnan	1.091	1.019	1.019	1.019	1.019	1.019	1.525	1.019	1.019	1.019
Systan - Baluchistan	0.881	0.881	0.881	0.881	0.896	0.881	0.881	0.6	0.881	0.881
Gharb	1.224	1.222	1.222	1.222	1.222	1.222	1.222	1.222	1.057	1.222
Kerman	1.04	0.989	0.989	0.989	0.989	0.989	0.989	0.989	0.989	1.492
Kish	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15
Gilan	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Mazandaran	1.181	1.181	1.181	1.323	1.181	1.181	1.181	1.181	1.181	1.181
Hormozgan	1.109	1.018	1.051	1.051	1.018	1.051	1.018	1.051	1.018	1.018
Yazd	0.538	0.538	0.539	0.967	0.538	0.539	0.538	0.54	0.538	0.538
Khuzestan 3	1.147	1.124	1.124	1.338	1.124	1.124	1.124	1.124	1.124	1.124
Fars1	1.132	1.046	1.046	1.087	1.046	1.046	1.046	1.046	1.046	1.046

Table 26: Efficiency results for SDEA with noisy data ($\alpha=0.7$)

$\alpha=0.7$	1	2	3	4	5	6	7	8	9	10
Esfahan	3.551	3.551	3.551	3.551	3.551	3.551	3.551	3.551	3.551	3.551
Azarbayejan	3.126	2.393	3.126	3.126	3.551	3.126	3.126	3.126	3.126	3.126
Bakhtar	2.918	2.918	2.885	2.942	2.918	2.918	2.918	2.918	2.944	2.918
Tehran	3.424	3.424	3.424	3.424	3.424	3.424	3.424	3.424	3.424	3.424
Khorasan	3.484	3.484	3.484	3.484	3.316	3.484	3.484	3.484	3.484	3.484
Zanjan	3.512	3.512	3.512	3.512	3.512	3.512	3.512	3.512	3.512	3.512
Semnan	2.545	2.545	2.545	2.558	2.545	2.545	2.521	2.545	2.57	2.545
Systan - Baluchistan	2.283	2.283	2.283	2.283	2.593	2.283	2.283	1.712	2.283	2.283
Gharb	3.517	3.517	3.517	3.517	3.517	3.517	3.517	3.517	3.517	3.517
Kerman	2.472	2.472	2.472	2.472	2.472	2.483	2.472	2.472	2.513	3.157
Kish	11.604	11.604	11.604	11.604	11.604	11.789	11.604	11.604	11.605	11.604
Gilan	4.764	4.764	4.764	4.958	5.338	4.764	4.764	4.764	4.764	4.764
Mazandaran	3.334	3.334	3.334	3.532	3.334	3.334	3.334	3.334	3.334	3.334
Hormozgan	1.242	1.242	1.242	1.742	1.298	1.242	1.242	1.242	1.242	1.242
Yazd	0.991	0.991	0.991	2.369	0.991	0.991	0.991	0.991	0.994	0.991
Khuzestan 3	1.633	1.783	1.633	2.896	1.633	1.633	1.633	1.633	1.633	1.633
Fars1	2.944	2.944	2.944	2.944	2.944	2.963	2.944	2.944	2.944	2.944